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Introduction

One of the chief scientific aims of geodesy is the determination of the size and shape of the earth. Therefore, much of the energy expended by geodesists has focused on finding a model (defined by both geometrical and physical parameters) that can serve as a suitable reference surface for further geodetic and geophysical investigations. 'Suitable' is a flexible term. In the 19th century, it may have implied accuracy to one part in 10^4 . Nowadays, it signifies better than one part in 10^8 .

Another equally important aim of geodesy is to provide a rigorous and precise basis for surveying and mapping. An internationally accepted reference model expedites cooperation between countries and serves as a secure foundation on which to support expensive and time-consuming projects. Toward this aim, permanence, or at least longevity, is as vital as accuracy.

The purpose of this article is to cover the development of recognized models for the figure of the earth during this century. The determinations of the earth's scale, by Eratosthenes in the 3rd century B.C., and of its flattening, by the Pen-Lapland expeditions in the 18th century, are well known to most scientists. But the remarkable improvements occurring in recent times are not generally appreciated outside of the narrow geodetic community.

By "recognized models" we mean those that have received a measure of official approval by the International Association of Geodesy (IAG) and its covering organization, the International Union of Geodesy and Geophysics (IUGG). Thus this narrative, in large part, is a history of deliberations of the IAG. Much of the interest centers on the reaction of the IAG to the conflicting requirements induced by the two aims mentioned above.

The prototype model for the figure of the earth is a biaxial ellipsoid of revolution which is completely specified by two geometric parameters. Let a and b be the semimajor and semiminor axes of this model. The flattening f is defined by $f = (a - b)/a$. Customarily and conventionally, a and b are the two parameters designated. If geometric quantities, like arc measurements and relative station positions, are all with which one is concerned, then such a model is adequate. However, once physical properties are considered, a less simple approach must be taken. For the computation of gravity on the model, it is obvious that one has to introduce some information on the mass of the earth, that is, a third parameter. Furthermore, it is also obvious that this value of gravity is

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Cover: Small impact crater near Taal volcano: Crater is only 0.1 in diameter, and it shows the shock waves left by the impact of a bomb tossed out of the crater in the 1965 eruption. (Photo courtesy of the U.S. Geological Survey)

influenced by the fact that the earth is rotating, indicating the need for a fourth parameter. But this suffices. Earth models are now usually defined by four parameters (plus a designation of the orientation of the axis of maximum inertia in inertial space).

Thus it can be inferred that a legitimate model, which should be able to handle both physical and geometric chores, might be an ellipsoid of revolution of mass M , rotating at angular speed ω , and hence defined by a parameter family (α, i, M, ω) . It is shown in standard texts [e.g., *Heiskanen and Moritz*, 1967, pp. 64-67] that if the constraint is imposed that the surface of the model be level (i.e., equipotential), then the exterior gravitational field generated by this configuration is unique (the so-called Somigliana field). Note that no assumption has been made about the distribution of mass within the model. This model is designated as a normal ellipsoid.

The accuracy of the model depends on how well the numerical values of the parameters are chosen. In order to accord with reality, they should be based on the best observational data available: a has always been comparatively well determined from arcs of triangulation; ω depends on straightforward astronomical measurements; however, in two instances, M and f , the observational material is relatively weak. Fortunately, these particular parameters can be replaced by equivalent quantities that are much better determined. Consider the product GM , where G is the universal constant of gravitation. One need be familiar only with Newton's law of gravitation to realize that in dealing with any measurement involving the earth's gravity field (and thus bringing into play physical considerations), whenever M appears, it is in the guise of GM . Modern measurement techniques which employ artificial satellites and planetary probes have refined the value of GM to 1 part in 10^4 , whereas M itself is known only to about 1 part in 10^3 . Prior to the artificial satellite era, the best determined quantity relating to the earth's gravity field was surface gravity itself. It was thus customary to accept as a parameter in place of M the equatorial value of gravity γ_e , whose unique relation to the other parameters is spelled out in Heiskanen and Moritz (1967, p. 891).

Historically, a variety of geometric and physical methods have been employed to determine f . A complete record can be found in the monograph by Strasser [1957]. However, up until 1957, when the first artificial Earth satellite was launched, accuracy was good only to hardly better than 1 part in 100. (Strasser's account goes through 1853.) Then, almost immediately, an equivalent parameter was determined from observations on artificial satellites to at least an order of magnitude better. This parameter, the dynamical form factor, designated by J_2 (because it is the coefficient of the second zonal harmonic term in the spherical harmonic expansion of the earth's exterior potential field), is directly related to f for a normal ellipsoid by a closed formula involving just the other independent parameters [Heiskanen and Moritz, 1967, p. 73]. Thus the modern definition of the normal ellipsoid is by means of the parameters a , J_2 , GM , u .

We stress again that a particular normal ellipsoid generates a unique exterior gravitational field. This field can be specified by an infinite set of coefficients J_n ($n = 2, 4, 6, \dots$) that correspond to the even zonal harmonic terms in the spherical harmonic expansion of the earth's potential. However, all J_n for $n > 2$ are functions of the parameter set $\{a, J_2, GM, \omega\}$. It is interesting to consider the range of parameter sets that can simulate closely the actual gravitational field. For example, one can take the real value of J_2 but set $\omega = 0$. In that case, λ would be about 1700, less than half the real value. But although J_2 is enforced to be the same, the other J_n will change, and thus the property of uniqueness is honored.

Because the potential is constant on the surface of the normal ellipsoid, its value U_0 (units: m^2s^{-2}) could replace a as one of the defining parameters. This has a certain appeal, since the set (U_0, J_2, GM, a) relates directly to the physical situation (cf. also *Bulletin Gèodésique, New Series* 118, 1975, p. 402). However, U_0 suffers from the same observational deficiency as M : a is much more accurately measured.

Recapitulating, the modern accepted model for the figure of the earth is the normal ellipsoid, defined thus: (1) Its geometric shape is that of an ellipsoid of revolution with semi-major axis a and flattening f . (2) The mass of the ellipsoid is M . (3) The ellipsoid rotates at angular speed ω . (4) The surface is level.

Under these assumptions the exterior gravitational field is completely determined, although the interior field is not. However, the choice of the four defining parameters constrains the possible distribution of mass within the model. For example, if the additional assumption were made that the model is in fluid equilibrium, then this would force the density to be homogeneous. If we wish to retain an Earthlike density distribution along with conditions (2), (3), and (4), then (1) becomes distorted into a fourth-order surface that requires an additional parameter for complete delineation. For a more generalization of discussion of this topic, see Moritz [1988].

Specifications for a unified model (like the normal ellipse) that is suitable for both geometric and physical applications were not formulated until this century was well underway. However, the requisite theory had been available in Friedrich Helmer's monumental treatise (*Helmer*, 1880). At the beginning of the century, these were much actively to determine

ning of this century; these ellipsoids would serve as reference figures for large triangulation systems and to set up standard gravity to which values that were derived from a simple mass configuration from which gravity anomalies could be computed. Measured values of gravity itself served as a basis (and, according to Helmert, the best basis) for determining the geometric flattening, the link being through the classic (18th century) formula of Clairaut. The name of Helmert pervades all research in this field during this period. In 1901, he published a value for f , 1/298.3, which was based on gravity measurements. Five years later, he computed a to be 8,378,140 m, based on European arc measurements and the aforementioned value of f . The correctness of this set to presently accepted values is

almost uncanny. An element of luck is surely present here, because, upon adding more data, Helmert's values of a in a subsequent solution increased to 6,378,200 m.

Also, at the beginning of this century, a large effort was mounted at the U.S. Coast and Geodetic Survey, under the leadership of John Hayford, to determine a reference ellipsoid by applying a principle heretofore untried for this purpose. The method employed by Helmert was to minimize (in the sense of least squares) the observed deviations of the actual Earth from an ellipsoid of revolution by treating these deviations as random. Hayford realized that the observations could be biased because of their poor distribution and relative paucity. He therefore applied the theory of isostasy as a corrective process to his observations, all in the U.S. A preliminary solution was announced by Hayford at the 1906 General Conference of the International Geodetic Association (the progenitor of the International Association of Geodesy), and a revised solution, based on additional data in the U.S., was presented at the next general conference, held in 1908. This last solution consisted of $a = 6,378,388$ m and $f = 1/297.0$. The time was ripe for official international agreement on a standard model to which geodetic triangulation, now overruling national boundaries, could be referred. World War I interrupted such considerations.

However, the question was raised at the constitutive assembly of the IUGG in Brussels in 1919, and was formally discussed at the first general assembly of the IUGG, held in Rome in 1922. At the meeting of the then-termed Section of Geodesy (the title of Association came into effect in 1932 and of International Association in 1946), William Bowie brought up the distinction between the scientific and the practical purposes for a choice. The former required the best (i.e., the most accurate) determination, whereas the latter simply demanded unanimity among the national geodetic organizations. A resolution passed by the assembly in Rome advocated (modestly) a common reference ellipsoid for all nations on the same continent. The next general assembly was held in Madrid in 1924. Just before the assembly convened, the executive committee of the Section of Geodesy agreed that the Rome resolution be modified to consider a single ellipsoid for all continents. A great deal of spirited discussion ensued during the general sessions. Although feeling was practically unanimous on the need for an International reference ellipsoid, the choice of parameters was controversial. In particular, the British delegation favored a rounded set of values (i.e., the semimajor axis specified to only five significant figures). Because Hayford's value of f matched fairly closely (i.e., to within the stated standard errors) the result obtained from Helmert's gravity investigations, and because it gave the impression of being a rounded value ($1/297.0$), there was little opposition to it. On the other hand, the choice of a was bitterly contested. Hayford's result was criticized because it was based solely on measurements in the U.S. and because its seven significant figures were too many to be believable. Bowie defended the Hayford value by arguing that the application of the theory of isostasy and the varying terrain in the U.S. sufficiently generalized the solution. Moreover, he was against rounding, because the exact result made it clear on what basis the values were chosen and to what the standard errors referred. Hayford's value of 6,378,388 m was narrowly approved by a vote of 19 to 17.

Thus, for the first time, a reference ellipsoid was officially recognized by the international geodetic community. It was termed the International ellipsoid. There are two interesting footnotes regarding this choice. First, although the geodesists waited until 1924 to take organized action, at a meeting of the International Congress of Astronomical Ephemerides, in Paris in 1911, the delegates gave an official astronomical imprimatur to 1/297.0, an anticipatory action that was repeated, *vis-à-vis* the geodesists, in later years. Second, although an American result was apotheosized internationally, the U.S. had no intention (and Bowie announced this in advance) of converting its own national triangulation system to the newly crowned reference model because it did not deem the required effort as necessary or worthwhile.

Soon after the choice of this set of geometric parameters, **Lambert** [1928] raised the question of the desirability of determining a formula for theoretical gravity that was compatible with the International ellipsoid as a level surface. **Cassinis** [1930] published the definitive formulas, based on the work of Pizzetti and Somigliana (**Helsinki** and **Moritz**, 1967, p. 70), and proposed the numerical values

$$\gamma_e = 978.049 \text{ Gal} (1 \text{ Gal} = 10^{-2} \text{ ms}^{-2})$$

These, combined with the international ellipsoid values of a and f , formed the basis for defining the international gravity formula, adopted at the 4th General Assembly of the IUGG Stockholm in 1930. A complete set of parameters for an internationally recognized normal ellipsoid had now been established.

After this, the question of revision of these parameters lay dormant within the geodetic establishment for 30 years. This was not due to lack of scientific progress in improving their values. Hayford's semimajor axis was generally recognized to be too large. By omitting doubtful observational material,

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FEBRUARY 10, 1981

[illegible][illegible]

3130 Ground Water ANALYSIS OF THE RECIPROCALITY CONCEPT IN POROUS MEDIUM.
G. K. Falade (Department of Petroleum Engineering, University of Ibadan, NIGERIA).
The general Reciprocity Relation was proved to be valid for flow of fluid through porous medium. The validity was demonstrated for flow within a bounded infinite domain and also for a finite domain bounded by impermeable boundaries. A graphical analysis of the Reciprocity Relation was presented for the bounded system.

Water Resour. Res., 1980, 16, 501-511

[illegible][illegible]

2160 Runoff and streamflow
THE PREDICTION OF RIVER WATER TEMPERATURES
K. Smith, Department of Geography, University of
Bristol, 26 Richmond Street, M3 0PL
Temperature is arguably the most significant
single determinant of water quality but data
are often lacking at relatively few locations
and are rarely suitable for systematic analysis.
This paper details two different methods suitable
for the use of managers engaged in predicting river
temperature for a range of purposes, such as
assessment of the needs of fish and the
management of water uses. Firstly, simple linear
regression equations are presented for estimating
river temperature from a small number of
acceptable level of accuracy may be required.
Secondly, it is shown how a
regression equation may be fitted to short term
observations of river temperature to
represent the characteristic seasonal and diurnal
variations in river water temperature.
Hydrological Sciences

3160 Optimal and near-optimal
OPTIMAL SCHEDULING OF THE HYDRO SCHEDULING FROM THE
PRINCIPLE OF PROGRESSIVE OPTIMALITY OPTIMALITY
Andrei Yurganov (Hydro-Quebec, Verano, Que.,
Canada J0L-2P0)
This paper presents an algorithm based on the
principle of progressive optimality for determining
the optimal short-term scheduling of multi-
reservoir power plants; the method takes into
account water head variations, spillings, and time
delays between upstream and downstream reservoirs.
The algorithm is computationally efficient and has
minimal storage requirements. The convergence in
monotonic and a global solution is not guaran-
teed by dynamic programming, the state variables
do not have to be discretized with this method.
An extensive analysis of four hydroplants in series
is solved and the results of the analysis are presented.
Water Resour. Res., Paper 1W071.

3170
AUTOMATED SYSTEMS FOR COLLECTING GROUND AND RELATED
HYDROLOGICAL DATA IN MOUNTAINOUS OF THE WESTERN
ROBERT S. Ballison (Engineering Division, Soil
Conservation Service, PO Box 2690, Washington, DC
20516)
Snowmelt runoff, primarily from mountains, contributes about 75% of the water supply in the
western United States. Ground water and related
hydrological data have been scarce and related
data sites for more than 40 years primarily
throughout the mountainous regions. A new
collection system called SNOGWL (for snow
water logging) is being installed. A portion of
the system, including the data acquisition and
1979, and installation of the entire system of
the system, is being completed. The system is
expected to be completed by November 1980.
Sensors to measure snow water content, snow
depth, and snow water equivalent are being
standard at each SNOGWL site. The system
will eliminate the need for manual
measurements at each SNOGWL site. The data
sites in the snow data network. The SNOGWL
transmission system has minor trials to
be completed. The system is being installed
station. The system, which operates in real
time, is capable of collecting and trans-
mitting data from the snow to SNOGWL
sites. It is made up of digital or analog sensors
at each SNOGWL site and a collection system
hydrological practices will, with the

which one is concerned. However, once physical example approach must be on the model, it is information on the matter. Furthermore, it is

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TRANSACTIONS

The Week

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Cover: Small Impact
in diameter, and it shows
a hole in the ground.

the Coast and Geodetic Survey's refinement of Hayford's computations indicated a decrease in a of about 160 m [Schmidt, 1953], independent determinations by Krasovskiy in 1940 [Strasser, 1957, p. 74] and Chovitz and Fischer [1956], which used newly available long arcs, confirmed the elephantine size of the officially adopted value. However, two reasons lay behind a lack of interest in change. The first, held by the 'practical' geodesists, was that the purpose of the normal ellipsoid was to serve as a fixed reference. The deviation of the reference from reality was not crucial, but its meaningfulness as a reference would be dissipated if it were frequently altered. As one well-known geodesist exclaimed in a discussion on this subject during this period, 'A cube could serve the purpose adequately.' This point of view, satisfactory as it may have been to those in charge of preparing national geodetic networks and cartographical products, offended 'aesthetic' geodesists. However, the latter were held back by the second reason, which was the wide discrepancy in accuracy of determination among the parameters. A revision in a , based on latest knowledge, would have reduced its error from 4 to 2 parts in 10^5 . But there was not much point in attending to this while an error of almost 1 part in 10^5 remained in f .

As mentioned earlier, observations on artificial Earth satellites, beginning in 1957, provided a breakthrough—indeed, the most spectacular, perhaps even the most significant, in the history of geodesy. An analysis of these developments is not within the scope of this article, which is intended to present an overview of the history of the adoption of official reference models. We simply mention that after the first order-of-magnitude jump in accuracy of f through its surrogate J_2 , a steady cumulative improvement continued to flow in for J_2 and GM from a variety of space-based observations. Just as important a factor in opening up the question of improved reference models was a psychological shift in geodetic viewpoints around this time. An influx of people who were trained primarily in other fields like astronomy and engineering influenced the classical geodetic outlook. In retrospect, it is not surprising that the astronomers took the first concrete official step toward revising the International ellipsoid, since they were unaffected by the burden of recalculating triangulation points or map corners.

The International Astronomical Union (IAU), organized the same year as the IUGG. In 1919, faced a much broader problem—that of reviewing and formalizing a system of astronomical constants. The four parameters that defined the normal ellipsoid occupied the IAU only peripherally. However, once it was decided to consider revisions, it was logical to examine critically all the constants in current use. In particular, the International ellipsoid values of a and f , and the International gravity formula of 1930 were part of this system. In May 1953, the IAU organized a special symposium in Paris on the system of astronomical constants. It was agreed that a working group would be formed to prepare recommendations to be presented formally to the next IAU General Assembly, which would take place the following year. But before then, and just after the Paris symposium, the IAU held its 13th General Assembly in Berkeley. The Paris meeting was duly noted, and a small committee was formed to serve as liaison with the IAU 'to make known the point of view of the IAG' [Bulletin Géodésique, New Series 70, 1963, p. 304]. But the conservative bent of the IAG was evidenced by the passage of a resolution that 'no change should be made at the present time in the International gravity formula' [Bulletin Géodésique, ibid, p. 408].

At the IAU General Assembly in Hamburg in 1964, the following parameters were adopted: $a = 6,378,160$ m; $J_2 = 0.0010827$; and $GM = 398,603(10^9)$ m³/s². From other primary astronomical constants, one can derive [Bulletin Géodésique, 1970] $\omega = 7.2921151467(10^{-5})$ rad s⁻¹. The corresponding value of f is 1/298.25.

Although no uncertainties were listed, the IAU working group that made the recommendations stated that 'the true values of the primary constants are believed to be between the following limits: $a = 6,378,080$ to $6,378,240$ m; $J_2 = 0.0010824$ to 0.0010829 ; and $GM = 398,600$ to $398,608(10^9)$ m³/s²' [Bulletin Géodésique, New Series 75, 1965, p. 63]. The values of J_2 and GM were based on space observations, while that of a depended primarily on the recent geodetic arc measurements. (For example, the solution of Chovitz and Fischer [1956] yielded a value of $6,378,135 \pm 30$ m if it were fixed at 1/298.25.)

The IAG was thus presented with a fait accompli when its 14th General Assembly met in 1967 in Lucerne. There was still an attitude of ambivalence, as shown by this passage (freely translated from the French) from the report of J.-J. Levallois, the IAG Secretary General:

The Association cannot indefinitely give the impression that it has no interest in this question and let other organizations make the decisions which are incumbent on it, even if—as it appears to be the case—the problem does not appear to be of fundamental importance to its proper work. [Bulletin Géodésique, New Series 86, 1967, p. 317.]

The IAG proceeded to pass a resolution, confirmed by the IUGG, that set up a Geodetic Reference System 1967 to supplant the 1924–1930 International model. The parameters selected were identical to the ones chosen by the IAU. In order to stress that the IAG had not been left completely in the lurch, the resolution contained the somewhat plaintive phrase, 'considering . . . that the IAU in consultation with the IUGG has adopted . . . [Bulletin Géodésique, ibid, p. 367; italics added for emphasis]. The bald fact was that the IAU had taken the lead in a matter which traditionally was the responsibility of the IAG.

In a manner of making amends, the IAG authorized and carried out a definitive development of derived constants and tables for the normal ellipsoid. These were published in a special issue of the Bulletin Géodésique [1970], and they contained a new standard gravity formula to replace that of 1930. The change in the value of γ_e (cf., table of official val-

ues of parameters) was due largely to an updating of the reference origin for absolute gravity. In addition, a detailed analysis of the effect of the atmosphere was made. The atmosphere has discernible mass, which artificial satellites 'consider' to be part of M . On the other hand, it is exterior to the surface. The problem is resolved by condensing the mass onto the surface. For points inside the atmosphere (as opposed to points outside, like artificial satellites), a correction table was prepared to be added to measured gravity. The correction varies from 0.87 mGal at the surface to 0.01 mGal at 32-km height.

The Geodetic Reference System 1980

Even at the time of the 1967 General Assembly, sufficient new data had been amassed that it was recognized that the 1967 parameters could be already improved. For example, Vels [1968] published $a = 6,378,142$ m, $GM = 3,986,009(10^9)$ m³/s², and $J_2 = 108,263.9(10^{-6})$, based on a combination of the latest space and terrestrial observations. But the only action taken in this respect at the 15th General Assembly of the IAG and IUGG in Moscow in 1971 was to confirm the 1967 normal ellipsoid by adopting the special publication of the Bulletin Géodésique [1970] as the official statement of the IAG about a reference model. However, the IAG initiated a more positive attitude than in the previous decade. Perhaps it had the premonition that the IAU would revise its 1964 set of astronomical constants at its general assembly to be held in 1976. At a meeting of the IAG Executive Committee in February 1974, a special study group of the IAG was authorized. Their charge was to advise the IAG on the most up-to-date values of 'fundamental geodetic constants', of which the four parameters of the normal ellipsoid constituted a subset.

Accelerated activity by the IAG, starting in 1974 and culminating eventually in the replacement of the 1967 reference system, was mainly due to the work of this study group, and in particular to the energetic leadership of its president, Helmut Moritz.

For the 16th General Assembly of the IAG at Grenoble in 1975, the study group recommended the following values as 'currently representative estimates': $a = 6,378,140 \pm 5$ m; $J_2 = 108,263 \pm 1(10^{-6})$; $GM = 3,986,005 \pm 3(10^9)$ m³/s²; $\omega = 7.292,116(10^{-5})$ rad s⁻¹.

The change from the 1967 set is not trivial. Both J_2 and GM are given to one higher order of magnitude, and a is altered by 1 part in 300,000. The reasons for rounding ω down from 11 to 7 significant digits were, first, because variations of the annual mean value of ω could affect the eighth figure, and, second, seven digits correspond to the accuracy of the other parameters.

This set was presented as part of a more comprehensive collection of constants, including values of other spherical harmonic coefficients of the earth's potential field. Thus the overall group of constants does not define a normal ellipsoid. This was not the intent of the study group, since in its report [Bulletin Géodésique, New Series 118, 1975, p. 405] it advocated that the Geodetic Reference System 1967 remain 'the system officially recommended by the IAG, because too frequent a change is not advisable.' The IAG took this advice by approving, at Grenoble, a resolution that listed the values given by the study group 'as currently representative estimates' but also stating that 'this resolution does not affect the validity of the Geodetic Reference System 1967 for reference purposes.' Again, the conflict between the two purposes of an official reference system was manifested. A large segment of the delegates at the assembly took the point of view that a reference system loses its authority and cannot be taken seriously if it is frequently changed. (Perhaps there is a vague analogy with modern automobiles whose models are changed annually.) On the other hand, the argument that change was costly to those in charge of issuing geodetically related products did not carry as much weight as before because of the availability of high-speed computers for effecting numerical transformations. Nevertheless, the IAG had postponed any official revision of its 1967 reference system until at least 1979.

The IAU did not labor under any such compunctions. At its 1976 General Assembly, also in Grenoble, it adopted as part of its latest set of astronomical constants the same values for a , J_2 , and GM as had been recommended by the IAG study group and acknowledged by the IAG the year before.

The questions to be considered and resolved by the IAG at its next general assembly, at Canberra in 1979, were: first, should the 1967 reference system be changed, and second, if so, should the IAG again follow in the footsteps of the IAU or strike out boldly on its own. The specific recommendations in this matter again devolved on Moritz's study group, the tenure of which had been extended until the Canberra assembly. It is intriguing that attitudes and actions paralleled very closely what had occurred at the 2nd General Assembly in Madrid 55 years before. Concerning the first question, a strong majority of the study group members advocated that a new official reference system be adopted. The second question was not as easily resolved. The study group revised the 1975 'currently representative estimates' as follows: $a = 6,378,137 \pm 2$ m; $J_2 = 108,263 \pm 1(10^{-6})$; $GM = 3,986,005 \pm 0.5(10^9)$ m³/s²; $\omega = 7.292,116(10^{-5})$ rad s⁻¹.

Of these, GM , J_2 , and ω were not controversial; no recent evidence (except for additional data confirming the value of GM) had turned up to refine the values named by the study group in 1975 and subsequently adopted by the IAU. But a great deal of new evidence had accumulated for a , especially from the altimeter data acquired from the GEOS 3 satellite. The value $6,378,140$ m implied an accuracy to six significant figures, whereas it was now believed that the uncertainty in a had been reduced to 2 or 3 m at the most. The latest solution pointed to $6,378,137$ m as the most likely value if a list—this was future refinements could very well converge on 136 or 138, and so seven figures should not be listed until one is sure of the seventh figure. The proponents of seven figures believed it was better and more accurate to be in error possibly by a meter or two than to neglect entirely the info-

Forum

GIFT

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AGU Committee on
Education and Human Resources

Whenever potential uses of an endowment fund have been discussed, the needs for scholarship assistance have been emphasized and given high priority. This point should have been included in the initial brochure, 'AGU—Girding For Tomorrow,' of the appeal. We will have other opportunities to restate the goals. A 5-year effort has many 'windows.'

Through the fine work of your committee and others, the Union has undertaken a modest scholarship program. The support for this program has been charged to 'operational' funds and not drawn from the income of the existing endowment fund. The 1981 budget adopted by the Council at its December meeting in San Francisco includes grants for the continuing program to encourage students from minority groups to enter geophysics (see *Eos*, March 11, 1980) and for the Congressional Science Fellow Program. There is a scholarship for a woman in the atmospheric sciences funded through gifts from June Bacon-Bercy. Also, the income from the Berkner Fund, which is being treated as an endowment fund, is being used to pay dues for an initial 3-year period for young geophysicists who live in developing countries. We believe that about 50 such grants can be made each year.

I recognize that these examples are mere tokens of the type of scholarship program that might be developed under a well-supported endowment fund. I hope that other members of AGU are as concerned as you. There are opportunities for donors and groups of donors to identify their gifts as a scholarship fund in memory of a colleague or former professor. These are decisions for the donors.

Charles A. Whitten
Earl G. Droessler
Cochairmen, GIFT Steering Committee

mation provided by the seventh figure. Compatibility with the IAU was not a concern because the slightness of the change would have insignificant effect on the system of astronomical constants (P. K. Seidelman, private communication to H. Moritz, 1978).

At the 17th General Assembly of the IAG, at Canberra in December 1979, an entire half-day was devoted to a presentation and discussion of the proposed reference system. The 'bold' approach triumphed by a large margin than the correspondingly bold action taken by the Second Assembly at Madrid in 1924. (Since the number of delegates was much greater, an actual vote count at Canberra was neither feasible nor needed, majority sentiment being readily evident.) Thereby, the IAG forwarded to the IUGG the following resolution, which was approved and published as IUGG Resolution No. 7.

IUGG recognizing that the Geodetic Reference System 1967 adopted at the XIV General Assembly of IUGG, Lucerne, 1967 no longer represented the size, shape and gravity field of the Earth to an accuracy adequate for many geodetic, geophysical, astronomical and hydrographic applications and

Considering that more appropriate values are now available,

Recommendations
(a) that the Geodetic Reference System 1967 be replaced by a new Geodetic Reference System 1980, also based on the theory of the geocentric equipotential ellipsoid, conventional constants defined by the following equatorial radius of the Earth:

$$a = 6,378,137 \text{ m}$$

geocentric gravitational constant of the Earth (including the atmosphere)

$$GM = 3,986,005 \times 10^9 \text{ m}^3 \text{ s}^{-2}$$

Size and Uncertainty of Parameters

Parameter, units	Order of Magnitude	Uncertainty, ca. 1980	Uncertainty, 1980
a , m	$6(10^6)$	$1/2(10^4)$	$1/3(10^4)$
J_2	$1/300$	$1/10^5$	$1/10^5$
GM , m ³ s ⁻²	10^{-3}	$1/10^4$	$1/10^4$
γ_e , m s ⁻²	$4(10^4)$	$1/10^4$	$1/10^4$
ω , s ⁻¹	10^1	$1/2(10^5)$	$1/2(10^5)$
	$7(10^{-5})$	$1/3(10^5)$	$1/3(10^5)$

*This is an estimate of deviation from constancy rather than of uncertainty.

Official Values of Parameters

System	a , m	f	J_2	Parameter	GM , m ³ s ⁻²	γ_e , m s ⁻²	ω , rad s ⁻¹
1924–30	6,378,388	1/297.0	0.0010820*	3,988,933 (10 ⁹)	9.780490	7.282115 (10 ⁻⁵)	
1967	6,378,160	1/298.247*	0.0010827	3,986,03 (10 ⁹)	9.780318*	7.2821151467 (10 ⁻⁵)	
1980	6,378,137	1/298.267*	0.00108263	3,986,005 (10 ⁹)	9.780327*	7.282115 (10 ⁻⁵)	

*Computed from the other parameters.

dynamical form factor of the Earth, excluding the permanent tidal deformation:

$$J_2 = 108,263 \times 10^{-6}$$

angular velocity of the Earth:

$$\omega = 7.292,116 \times 10^{-5} \text{ rad s}^{-1}$$

(b) that the same computational formulas, adopted at the XV General Assembly of IUGG in Moscow 1971 and published by IAG, be used as for the Geodetic Reference System 1967, and

(c) that the minor axis of the reference ellipsoid, defined above, be parallel to the direction defined by the Conventional International Origin, and that the primary meridian be parallel to the zero meridian of the Bureau International de l'Heure adopted longitudes.

The phrase 'excluding the permanent tidal deformation' is intended to emphasize that the normal value of J_2 should be due entirely to self gravitation and exclude the effect of the sun and moon. Paragraph (c) precisely orients the normal ellipsoid in inertial space. This is vital because, for geodetic reference purposes, orientation is just as crucial as scale.

The IAG Executive Committee authorized the special study group to continue to monitor the state of the art in geodetic constants and to report at the next (1983) IUGG General Assembly. However, any recommendation at that time to

change the Geodetic Reference System 1980 is hardly conceivable. It is a fair guess that this latest model may see us through this century.

Acknowledgment

Much of the information in this article was culled from various issues of the Bulletin Géodésique, going back to its inception in 1922. I hope it will not be considered presumptuous of me to dedicate this article to the memories of Georges Perrier, founder and editor of the Bulletin Géodésique between the two World Wars, and Pierre Tardieu, editor from 1946 to 1951, and to their successors: Jean-Jacques Levallois, editor from 1952 to 1984, Michel Louis, editor from 1985 to 1975, and Ivan Mueller, the present editor. Of course, any errors in this narrative are solely my responsibility.

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News

Big Science Victim of Budget Game

In an apparent effort to make certain that the newly proposed cuts in the federal budget reach all factions, except of course those that involve the military-industrial complex, David Stockman, the key player of the 'budget game,' has leaked to the press some of his plans that could virtually eliminate many parts of big science over the next decade. Two agencies that are important in this respect, and important to a large proportion of the geophysical community, are NASA and NOAA. There are portions of the budgets of both of these agencies that because of military significance will go unscathed. Unfortunately the 'across-the-board' cuts proposed by OMB Director Stockman will have to be concentrated on the rest that are relatively indefensible from a military standpoint and that turn out to be the most science intensive.

In an account apparently leaked to the Chicago *Sun-Times* and reported by that newspaper on Feb. 4, 1981, Stockman, one of the inventors of the term 'economic Dinkirk,' is said to have placed the science-oriented segments of the federal government on a 'hit list.'

The projected cut to the NASA budget recently proposed by the Carter administration is stated to be on the order of \$830 million, amounting to almost 10%. It is true that the fiscal year 1982 budget request for NASA exceeded the fiscal year 1981 actual budget by upwards of 22%. The problem is that aside from inflationary increases, including supplementary salary rates that are beyond the control of the agency, the major portion of the increase is in space transportation, i.e., shuttle. Possibly shuttle itself may be curtailed in its later missions, but right now there is a great push, and there are extra costs to get shuttle off the ground.

The proposed budget cuts for NASA fit the overall effort of the new administration to place intense pressure upon the federal government. In this context, and in the context of a numerical 'budget game,' the cuts appear reasonable and, perhaps, logical. If these cuts are indeed made, their implementation will be less than logical. NASA would have to curtail its space science program by more than one third. In doing this, all new missions would have to be cancelled, and in essence there would be no effective space science program at all. The two new missions, Galileo and VOIR, would be scrapped. So would the Gamma Ray Observatory, the Upper Atmosphere Exploration Program—possibly the Space Telescope, and many others. One sees the perspective in realizing that if approved, the Stockman plan would virtually put the Jet Propulsion Laboratory at Cal-Tech out of business, and eliminate it as the world center of space research within the next few years.

The cuts to other agencies, for example, NOAA and the U.S. Geological Survey, have not been so specifically targeted at this time. Nonetheless, NOAA has been told that it can expect major cuts in its NOS satellite program and in the sea grant program. The NOS satellite program, which is funded at a level of several tens of millions of dollars, is to be eliminated entirely. The cut proposed for the sea grant program is slated at over \$21 million, which would mean a reduction of the program by one half in 2 years.

Some Washington analysts view the Stockman 'hit list' as a series of 'trial balloons.' Great resistance and outcry from the communities and sectors to be victimized possibly could reduce or, in some cases, even eliminate specific cuts. Because the budget has already been proposed to Congress by the outgoing administration, it is anticipated that many of the budget cuts proposed by the new administration may not be approved by the Senate and by the House. The congressional committees and subcommittees that handle these issues will be sensitive, hopefully, to the outcry of the nation.—PMB

'Wind Farm' Producing Electric Power

The nation's first 'wind farm,' featuring three of the largest advanced wind turbine systems, is nearing completion. The turbines are the seventh, eighth, and ninth wind turbines to be built under a portion of the federal wind energy program. The first of the three new machines began producing electricity for the Bonneville Power Administration at Goodnoe Hills, near Goldendale, Wash., late last year. The second machine will be fully assembled and begin to generate electricity in February. The third machine is expected to be fully assembled and running late this spring.

The three machines, each rated at 2500 kW, will be the first cluster of these experimental wind turbine systems. The new machines have been designed to bring the cost of wind-generated electricity very close to the cost of power generated through the burning of fossil fuels.

When all three are operating, by mid-1981, they will feed 7500 kW of electricity into the Bonneville power grid, enough to supply 2000 to 3000 average homes. Designated Mod-2, the machines are the largest and most powerful wind turbines ever built. The three Goldendale wind turbines, designed to have a system life of 30 years, were built by the Boeing Engineering and Construction Co. of Seattle, Wash., under contract to NASA-Lewis. Under earlier Department of Energy funded projects, started in 1974, NASA-Lewis built six smaller developmental units, ranging in power output from 100 to 2000 kW.

In terms of design, size, appearance, and performance, the new machines encompass significant modifications and advancements over the earlier models. These first three Mod-2 prototype wind turbines cost \$13 million to build and install. It is estimated that they will produce electricity at a cost of less than 8 cents per kWh. If these same machines were to be produced in quantities of 100 per year or more, the 100th wind turbine would provide power at a cost of less than 5 cents per kWh.

The Goodnoe Hills machines are set up in a triangular pattern, ranging from 480 to 915 m apart, to form a small turbine 'farm.' Engineers predict that farms of 25, 50, or 100 wind turbines may be producing truly significant amounts of cost-effective electricity by the end of the century.

The new, Mod-2 wind turbines are 61 m high and produce power from the rotation of their steel rotor blades, which measure 81 m from tip to tip. Each machine's rated power output of 2500 kW is achieved at a blade speed of 17.5 rpm in a rated wind speed at the top of the tower of 44 km/h. (Rated wind speed is defined as the lowest wind speed at which full power can be achieved.) The power output in relation to the wind speed is regulated by varying the pitch of the 13.7-m-long articulated blades tips.

It takes 22.5 km/h of wind to start the blades rotating, and at a wind speed of 72 km/h the machine is designed to shut itself off to preclude both excess stress on the blades and possible damage. However, in a stationary mode the machine can withstand winds up to 200 km/h. A drive train, including an improved, three-stage planetary gear box, converts the 17.5 revolutions of the blade into 1800 rpm of the generator.

Among the major design innovations and cost-savings modifications that have been incorporated into the Mod-2 wind turbines are:
Blade tip control: Unlike their predecessors, which were feathered along their full length, the speed of the Mod-2's blades is controlled by varying the pitch of only the 13.7-m-long blade tips. This has enabled designers to reduce rotor weight and cost.
Tower: Towers for all prior machines were of rigid truss design. These have been replaced by the more flexible,

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Bernard H. Chovitz is director of the Geodetic Research and Development Laboratory in the National Ocean Survey of NOAA. His educational background includes degrees in mathematics from the College of William and Mary and Harvard University. He has been working in the field of geodesy since 1948 when he joined the Army Map Service after a stint in the Navy during World War II. His principal interests in geodesy have been directed to theoretical aspects and to applications of satellites. He is a past president of the Section on Space Techniques of the International Association of Geodesy (IAG) and remains a member of the IAG Executive Committee. He has been actively involved in the IAG Geophysical Union, having coedited one of the monograph series, served as an associate editor of the *Rad JGR*, and recently completed a term as president of the Geodesy Section.

simpler, tubular design, a modification that has permitted the use of less expensive, factory-assembled components and an overall reduction in the amount of materials required for tower construction.

Rotor blades: The welded steel blades are fastened to the hub in a straight-line fashion and are positioned upward of the tower.

Through the use of a telescoping mechanism at the hub, the blade assembly is able to tilt as much as 6° in response to wind loads. This design feature reduces loads on all of the turbine components and has resulted in lower costs.—PMB

World Earthquake Activity Increases

The number of significant earthquakes in the world increased in 1980, and the earthquake death toll was up sharply, according to the U.S. Geological Survey.

USGS scientists said there were 71 significant earthquakes recorded in the world last year, compared to 56 the previous year and 62 in 1978. Eleven of the 1980 earthquakes occurred in the United States, compared to five the previous year and four in 1978.

Significant earthquakes are defined as those registering 6.5 or more on the Richter scale, or smaller ones that cause casualties or considerable damage.

About 7140 earthquake-related deaths occurred in 1980, nearly five times as many as in 1979, but still below the long-term average of 10,000 deaths per year.

Most of the deaths in 1980 occurred during or after the quakes in Algeria and Italy. More than 3500 persons were killed in a 7.3-magnitude tremor and a 6.2-magnitude aftershock in Algeria October 10, and more than 3000 persons were reported killed in a 7.2-magnitude quake in southern Italy November 23.

Study To Examine Wind-Driven Currents

The effects of the wind on currents along northern California will be examined under a \$6.4 million study beginning April 1. The 4-year program, called Coastal Ocean Dynamics Experiment (CODE), is funded by the National Science Foundation. Oceanographers from five institutions will participate.

Focus of the study will be on the physical conditions involved in ocean movement, including water and air temperatures, and wind speed and direction. CODE's overall objective is to identify and quantify the processes that govern wind-driven currents over the continental shelf along a 97-km stretch of California. Data from Point Arena to Bodega Bay will be collected by using moored instruments, floating buoys, shipboard observations, land-based stations, and aircraft.

CODE is a joint project of the Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, Oregon State University, the University of New Hampshire, and the U.S. Geological Survey.

'From a purely scientific viewpoint, we want to know the direction of the current, how fast it travels, and what forces drive it,' said Clinton Winant, one of the principal investigators and an oceanographer at Scripps. 'From an applied point of view, the study is important because of the increased use of coastal water by society—for disposal of wastes, oil exploration, and commercial fishing.' Winant continued, 'Knowledge of the coastal circulation will aid in management of these resources and the monitoring of potential hazards such as oil spills and other pollution.'

conditions at similar areas anywhere in the world. As part of the program two 4-month periods of extensive study are planned: one for April 1 to July 31, 1981, and another for the same time one year later. Ocean circulation at the shelf will be measured and recorded during these periods, Winant said.—BTS%

Project Aims to Improve Weather Predictions

Project Skywater, an atmospheric research program slated to begin this spring, will investigate basic precipitation problems, including the formation of raindrops, mechanisms by which air outside rainclouds mixes with air inside, atmospheric processes that lead to the birth and growth of a storm, and the origins of ice. These fundamental problems stand in the way of evaluating the potential of weather modification techniques and of predicting precipitation and severe weather," according to Bernard A. Silverman, project head.

As part of the project, researchers will work this summer on the Cooperative Convective Precipitation Experiment (CCOPE). Based in Miles City, Montana, CCOPE will study the lifetimes of summer clouds. The work will focus on the major natural processes that lead to precipitation in large cloud systems. In addition, researchers will investigate cloud chemistry and lightning's effect on rainfall.

About 125 scientists from 17 universities and more than a dozen private research groups will participate, Silverman said. Project Skywater is funded through the Department of the Interior's Water and Power Resources Service.

Geophysicists

Bernice Ackerman has been appointed head of the new meteorology section of the Illinois State Water Survey. She has been a professional scientist and a project leader at the Water Survey since 1972.



Filson

John R. Filson has been appointed chief of the Office of Earthquake Studies at the U.S. Geological Survey National Center in Reston, Virginia. He succeeds Robert L. Wasson.

Paul S. Julianne, a staff member of the Department of Commerce's National Bureau of Standards, received a bronze medal at the Eighth Annual NBS Awards Ceremony. The medal was awarded for his contributions to the development of theoretical descriptions of atomic collisions in intense electromagnetic fields.

New Publications

New Listings

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Geomorphology—A Systematic Analysis of Late Cenozoic Landforms. A. L. Bloom, Prentice-Hall, Englewood Cliffs, New Jersey, xvii + 510 pp., 1978.

The Geotectonic Development of California, Rubey, vol. 1, W. G. Ernst (Ed.), Prentice-Hall, Englewood Cliffs, N.J., xii + 706 pp., 1981, \$25.00.

Groundwater Hydrology—Second Edition, D. K. Todd, John Wiley, New York, xiii + 535 pp., 1980.

Illinois State Geological Survey: Its History and Activities, Educ. Ser. 12, R. E. Bergstrom, Illinois State Geological Survey, Urbana, iv + 41 pp., 1980.

IMS in Antarctica, Mem. Nat. Inst. Polar Res. Spec. Issue 16, T. Hirazawa (Ed.), National Institute of Polar Research, Tokyo, v + 144 pp., 1980.

The Interpretation of Ionic Conductivity in Liquids, S. I. Smedley, Plenum, New York, xvi + 195 pp., 1980, \$25.00.

An Introduction to Atmospheric Physics, 2nd Ed., Int. Geophys. Ser. Vol. 25, R. G. Fleagle, J. A. Businger, Academic, New York, xiv + 432 pp., 1980, \$29.50.

An Introduction to Atmospheric Radiation, Int. Geophys. Ser.—Vol. 26, K.-N. Liou, Academic, New York, xii + 392 pp., 1980, \$32.50.

Faculty Appointment/Colorado State University. The Department of Earth Resources, Colorado State University invites applications for a tenure track appointment with emphasis on active research experience in remote sensing, and an interest in teaching/teaching experience in geophysics. Responsibilities will include one-half time in active research and one-half time in teaching geophysics and supervising graduate students. The successful candidate will be familiar with exploration seismic data acquisition, processing, and interpretation. The Ph.D. or Masters with experience is required. Salary range is \$23,000 to \$35,000 per 12 month.

The position is expected to be filled in the Spring of 1981 or as soon as possible thereafter.

To apply please direct a resume, three letters of recommendation, and any other pertinent materials to: Dr. Gary L. Kinsland, Geology Department, University of Southwestern Louisiana, Lafayette, LA 70504.

Geologist/University of Washington. The University of Washington seeks applications for a tenure track position with the individual to be appointed as assistant professor/jointly the Department of Atmospheric Sciences and Geophysics program. Principal research interest of candidates should be directed toward geophysical or climate related study of snow or ice. Candidates specializing in physical processes in snow are of particular interest. All applicants must be committed to graduate level teaching, research advising, and innovative research emphasizing advanced experimental methods and rigorous physical analysis. Duties will include teaching one or two undergraduate courses per year in atmospheric sciences. The appointment starts in September 1981. A Ph.D. is required. For additional information call C. F. Raymond (206) 543-4914. Interested persons may send a resume and four letters of recommendation to Professor R. T. Merrill, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.

Oceanographic Mooring Technicians. The Marine Science Program at North Carolina State University (Raleigh) is expanding its oceanographic technical services group and is currently seeking a technician familiar with the design and deployment of deep-sea current meter moorings, as well as with standard shipboard oceanographic sampling techniques. Qualifications include a degree in science or engineering with some electronics background and two years field experience or an equivalent combination of education and experience. Salary commensurate with education and experience. Resumes and names of references to Personnel Services, North Carolina State University, P.O. Box 26087, Raleigh, NC 27650.

Virginia Polytechnic Institute and State University. Ignorance Petrology and Geochemistry/Research Associate. Origin and tectonic significance of granitic rocks. Project involves petrography, analytical chemistry, mineral chemistry, isotopic studies, and field mapping. Send resumes to: D. R. Wones, Chairman, Department of Geological Sciences, Virginia Poly. Inst. and St. Univ., Blacksburg, VA 24061. The University is an equal opportunity/affirmative action employer.

Faculty Positions in Geology/University of Alabama. The Department of Earth Science is seeking applicants for a tenure track position at the assistant professor level. The Ph.D. degree is required. The selected person will teach one or more courses in geology at the undergraduate level, others in earth science, will supervise senior independent research projects, will develop one or more elective courses in that person's specialty, and will develop a research program.

The Department of Earth Science consists of four full-time faculty and graduates approximately ten students each year. Equipment and facilities include a geochronological and sedimentation laboratory, rock preparation equipment, student research petrographic equipment, Bacon sedimentology equipment, transit and alidade, drafting facilities, and computer equipment. Salary is competitive and commensurate with experience and education.

Applicants should send a resume, three letters of recommendation, and a brief discussion of research interests to Michael J. Neilson, Earth Science Department, University of Alabama in Birmingham, Birmingham, AL 35294, prior to May 1, 1981. The position will be available September, 1981.

The University of Alabama in Birmingham is an equal opportunity/affirmative action employer.

Geochemistry/Brittle Deformation, University of New Brunswick. The Department of Geology has a tenure track position available from July 1, 1981 at assistant professor or higher level. The successful applicant will be expected to teach both undergraduate and graduate as well as carrying out research and supervising graduate students.

Applications will be accepted in the following fields: geochemistry of ore bodies, exploration, environmental or soil geochemistry, brittle deformation, rock mechanics or site engineering. Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three references should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 6A3.

Research Plasma Physicist. Berkeley Scholars, Inc. has opening in D.C. area. Must be eligible for Ph.D. in plasma physics with specialization in and abstracts presented on theory and numerical simulation of magnetic shear effects on instabilities phenomena as applied to ionospheric and magnetospheric problems. 1 year work experience in the field is required. Salary is \$24,416 per yr., 40 hrs. per wk. Send resume directly to Berkeley Scholars, Inc., P.O. Box 983, Berkeley, California 94701. An AA/EOE.

Physical Oceanographer/Geophysical Fluid Dynamist. Arete Associates, a growing research firm, located in Southern California, engaged in theoretical and empirical physical oceanography, is offering permanent, full-time positions. Candidates require Ph.D. (or equivalent experience) in physical oceanography or geophysical fluid dynamics. Salaries are competitive and negotiable, based on qualifications. Arete offers a fringe benefit package of superior quality. Qualified candidates should send resumes, salary history, and list of professional references to:

Personnel Administrator
Arete Associates
P.O. Box 350
Enino, CA 91316
An equal opportunity employer M/F.

Geophysicist. The Geology Department at the University of Southwestern Louisiana in Lafayette, Louisiana invites applications for an anticipated research/teaching position in geophysics. Responsibilities will include one-half time in active research and one-half time in teaching geophysics and supervising graduate students. The successful candidate will be familiar with exploration seismic data acquisition, processing, and interpretation. The Ph.D. or Masters with experience is required. Salary range is \$23,000 to \$35,000 per 12 month.

The position is expected to be filled in the Spring of 1981 or as soon as possible thereafter.

To apply please direct a resume, three letters of recommendation, and any other pertinent materials to: Dr. Gary L. Kinsland, Geology Department, University of Southwestern Louisiana, Lafayette, LA 70504.

Geologist/University of Washington. The University of Washington seeks applications for a tenure track position with the individual to be appointed as assistant professor/jointly the Department of Atmospheric Sciences and Geophysics program. Principal research interest of candidates should be directed toward geophysical or climate related study of snow or ice. Candidates specializing in physical processes in snow are of particular interest. All applicants must be committed to graduate level teaching, research advising, and innovative research emphasizing advanced experimental methods and rigorous physical analysis. Duties will include teaching one or two undergraduate courses per year in atmospheric sciences. The appointment starts in September 1981. A Ph.D. is required. For additional information call C. F. Raymond (206) 543-4914. Interested persons may send a resume and four letters of recommendation to Professor R. T. Merrill, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.

Deadline for application is 31 March 1981. An equal opportunity/affirmative action employer.

Structural Geologist. The Department of Geosciences of Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses, and pursue an active research program. Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and engineering geology and has a close working relationship with the geotechnical group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for applications is July 1, 1981. Applicants should send a resume, the names, addresses, and telephone numbers of three references, and a brief statement of research interests to R. H. McCullister, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

Staff Scientist/Ocean Margin Drilling Program. Joint Oceanographic Institutions, Inc. (JOI, Inc.) has immediate openings for two staff scientists to fill the positions of:

Field Programs Coordinator
Downhole Measurements Coordinator

In its Ocean Margin Drilling (OMD) Science Programs Office, individuals filling each of these positions will report to the OMD Chief Scientist. They will be required to provide staff support to advisory committees in their area of concern, and will be responsible for implementing programs recommended by the OMD Science Advisory Committee, including oversight of the performance of individuals or groups under contract to JOI. Both positions require a Ph.D. in an appropriate area of earth science and appropriate experience. The OMDP is funded for FY 81. Initial appointment will be for a period of two years with the second year contingent upon the availability of funds. The positions may be filled on a rotating basis. Salary will be competitive. Send resume, statement of interest, and the names of three references to Thomas A. Davies, Chief Scientist, Ocean Margin Drilling Program, Joint Oceanographic Institutions, Inc., 2600 Virginia Ave, NW, Suite 512, Washington, DC 20037. The deadline for applications is February 20, 1981, or as soon thereafter as suitable candidates are found.

Postdoctoral Research Associate. Oceanography Department of the Naval Postgraduate School seeks recent graduate to study the hydrodynamics, through numerical ocean modeling of the physical oceanographic processes active in the vicinity of the atollo lagoon edge of Alaska. Problem areas include the effects of the complex bathymetry on the circulation and frontal formation, the dynamics associated with the interaction of water masses at the ice edge, and the mechanisms involved in ice retreat. Research will be performed in the context of an observational program which has acquired data and developed insights over the course of several years. Position is available March 1981 and is renewable annually. Salary depends upon qualifications. Send resume and the names and addresses of three references to Faculty Search Committee, Dept. of Oceanography, Naval Postgraduate School, Monterey, CA 93940.

Equal opportunity/affirmative action employer.

Solid Planet Geophysicist/Texas A&M University. The Department of Geophysics at Texas A&M University is pleased to announce availability of a junior level, tenure track faculty position. The department emphasizes solid earth geophysics with concentrations in tectonophysics, geophysics, and internal structure. We are seeking a talented and active research-oriented and broad-based areas of expertise. There are excellent opportunities for interaction and collaboration with members of our department as well as those in the departments of oceanography and geology and in the center for geophysics. Qualified scientists are encouraged to send resumes to: Dr. J. W. Collins, Department of Geophysics, Texas A&M University, College Station, TX 77843.

Texas A&M University is an equal opportunity employer.

Assistant or Associate Scientist/Ocean Engineering. Research position in sediment transport and bottom boundary layer flows: must have background in turbulent boundary layer theory, laboratory or field boundary flow observation, low sediment interaction. Interest in biologically modified soil properties and statistics of spatially averaged data desirable. Will participate in several estuarine and deep ocean sediment transport boundary layer studies. Expected to collaborate with geologists, biologists, physical oceanographers, and ocean engineers in these studies. Opportunities to participate in graduate education program through advising students and formal courses. Recent graduates, up to five to ten years of experience with Ph.D. in engineering, geology, physics or mathematics. If interested, write to Department Chairman, Ocean Engineering Department, Box 64P, Woods Hole Oceanographic Institution, Woods Hole, MA 02543. An equal opportunity employer M/F/H.

Lunar Curatorial Laboratory Manager. Northrop Services, Inc. has operated and maintained the NASA Lunar Curatorial Laboratory at the Johnson Space Center, Houston, Texas since its inception. We are now searching for a manager candidate with a Ph.D. in geology or geochemistry, evidence of administrative skills and a record of publication in the study of lunar samples and/or meteorite investigations. Position involves the supervision of 38 technical, scientific and clerical employees. Interested persons should send resumes, including publications and references to W. B. Kurz, Manager of Personnel Services, Northrop Services, Inc., P.O. Box 34416, Houston, TX 77034.

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The Department of Geology of the University of New Mexico invites applications for the Vincent C. Kelley and Leon T. Silver Graduate Fellowships. The fellowships will be awarded on the basis of the scholastic record and academic promise of graduate applicants. Each fellowship will provide for a generous living stipend of \$1,000/month for 9 to 12 months, and up to \$2,000/year for travel and research expenses. The Caswell Silver Foundation will pay all tuition and university fees. The awards are made on an annual basis, but may be renewed for up to three years as long as the student maintains excellent academic standing and shows evidence of significant progress in research. Preference will be given to, but is not restricted to, applicants for the Ph.D. program.

An application for admission to the UNM Graduate Program, transcripts, Graduate Record Exam results (verbal, math & geology), three letters of reference and a brief statement of research goals are required for consideration for the fellowships. Application materials may be obtained from:

Rodney C. Ewing
Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

The deadline for applications is April 1, 1981 for the Fall semester of 1981.

The Caswell Silver Distinguished Professorship in Geology

THE UNIVERSITY OF NEW MEXICO

The Department of Geology of the University of New Mexico is pleased to invite nominations or applications for the Caswell Silver Distinguished Professorship in Geology. This endowed professorship shall be awarded for periods of up to two years to earth scientists of distinguished accomplishment and international reputation. The professorship may be held by scientists of all specialties of the earth sciences in the broadest sense, and the major criterion for selection is that the individual be an active, productive leader in his or her field of research. The recipient must carry out a vigorous research program while in residence at UNM. The recipient is expected to interact with the faculty and students of the Department and to provide one or more seminars, in an advanced topic of his/her choice, during each academic year. The Foundation will provide unusually advantageous remuneration commensurate with the distinguished nature of the appointment. In addition, a generous allocation for travel and operating expenses (to include secretarial support, analytical services in department laboratories, use of field vehicles, and preparation of manuscripts) will be provided.

Applications or nominations should include a detailed resume and brief statement of major research accomplishments. Applications or nominations should be forwarded to:

Rodney C. Ewing, Chairman
Department of Geology
University of New Mexico
Albuquerque, New Mexico 87131

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Resume, transcripts and three letters of reference should be submitted to: Prof. Lawrence D. Taylor, Department of Geological Sciences, Athlon College, Athlon, Michigan 49724.

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Director Meteorology Division, Air Force Geophysics Laboratory. Air Force Geophysics Laboratory invites applications for the position of Director of the Meteorology Division located at Hanscom Air Force Base, Massachusetts. The Division is responsible for Air Force research and development in meteorology, atmospheric physics, remote and direct sensing technology, climatology and relative technologies. The division director provides overall direction to an R&D program which employs over 60 people and covers a broad range of in-house and contractual scientific investigation. A candidate should have a record of distinguished achievement in meteorology/atmospheric physics as a research scientist and manager of a substantial R&D unit. This position is Air Force Senior Executive Service with a salary range of \$52,247 to \$57,673, subject to current \$60,112 ceiling. For an application package, call collect: Robert Ellerin, (617) 561-2896. To be considered, applications must be returned by 30 April 1981. Equal opportunity/affirmative action employer.

Marine Geologist. Dalhousie University, Department of Oceanography invites applications for a tenure track assistant, or possibly associate professor. The person appointed will be expected to develop a strong research program (for which funding opportunities exist through NSERC Strategic Grants in Oceanography) and to teach and supervise graduate students. We particularly solicit applications from people with interests in one or more of: sedimentology, stratigraphy, sedimentary geochemistry and paleo-oceanography. We actively cooperate with the geology department and the federal government (Bedford Institute of Oceanography). Applications with c.v.'s and names of three references should be sent before May 1 to Prof. C. Beaumont, Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, B3H 4J1, Canada. Telephone numbers are 902-424-3557/3779, Telex 016-21853, Dalhousie Oceanography.

Sediment Transport/Geological Oceanography, North Carolina State University. A tenure track position is available in the Department of Marine, Earth and Atmospheric Sciences at the level of assistant or associate professor. Applicants should have a thorough understanding of sediment transport, and a general background in geological oceanography. A Ph.D. is required. The candidate will be expected to strengthen the graduate teaching and research programs. The applicant's research interests should be theoretical, experimental, or observational, but must involve quantitative examination of marine sediment transport. Applicants should forward a resume, including a list of courses taken/taught, and the names of at least three references to: Dr. Charles A. Nittrouer, Chairman, Search Committee, P.O. Box 26068, NC State University, Raleigh, NC 27650. Application materials should be sent by March 31, 1981.

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Division Director Atmospheric Analysis and Prediction Division (AAP) National Center for Atmospheric Research (NCAR). The National Center for Atmospheric Research (NCAR) in Boulder, Colorado seeks applications and nominations for director of its AAP division, which concentrates on theoretical and observational studies of the dynamics and thermodynamics of the lower atmosphere. AAP's four sections emphasize climate research, large-scale dynamics, physical oceanography, and mesoscale research.

The position director is the scientific and administrative leader of the division, responsible for overall scientific productivity and excellence; short and long range planning, staffing, including affirmative action, and budget management.

The position requires a Ph.D. or equivalent in physical sciences; demonstrated scientific productivity and breadth in areas of AAP interest; equivalent to highest level NCAR scientific appointment; judgment about scientific quality, strategies and individual competencies; experience in management of activities and budgets; and ability as a scientific advisor.

Please send a letter of candidacy and a curriculum vitae to Dr. G. William Curtis, P.O. Box 3000, Boulder, Colorado 80507. (303) 444-5151, Ext. 550.

Applications should be received by 16 April 1981. The selected candidate should expect to assume position by 1 September 1981 or as soon thereafter as feasible.

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Acadia University. The Department of Geology, Acadia University, is seeking a head, beginning July 1, 1981. Preference will be given to applicants with experience and research interests in petroleum geology and related fields and/or energy resources. Rank and salary will be appropriate to qualifications. The successful candidate will assume leadership of an established, vigorous and growing department with five faculty members, and over 100 B.Sc. and M.Sc. candidates. Responsibilities include teaching at undergraduate and graduate levels, and academic planning and development in the specialty area.

A letter of application together with a curriculum vitae and names of three references should be sent by March 15, 1981 to Dr. Ernest E. Zink, Dean of Science, Acadia University, Wolfville, N.S., B0P 1X0.

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